

PREVIRNEC

A new platform for cognitive tele-rehabilitation

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Abstract — Acquired Brain Injury (ABI), either caused by vascular or traumatic nature, is one of the most important causes for neurological disabilities. People who suffer ABI see how their quality of life decreases, due to the affection of one or some of the cognitive functions (memory, attention, language or executive functions). The traditional cognitive rehabilitation protocols are too expensive, so every help carried out in this area is justified. PREVIRNEC is a new platform for cognitive tele-rehabilitation that allows the neuropsychologist to schedule rehabilitation sessions consisted of specifically designed tasks, plus offering an additional way of communication between neuropsychologists and patients. Besides, the platform offers a knowledge management module that allows the optimization of the cognitive rehabilitation to this kind of patients.

Keywords — *PREVIRNEC; tele-rehabilitation; cognitive rehabilitation; Acquired Brain Injury (ABI).*

I. INTRODUCTION

The World Health Organization (WHO) predicts that by the year 2020, stroke and traumatic brain injury (TBI) are within top five etiologies considering medical cost and cost of disability adjusted to life expectancy (DALY). These injuries produce a complex constellation of medical consequences including physical and cognitive deficits. Cognitive impairments in attention, memory, language, and executive function hamper the path to functional independence and a productive lifestyle for the person with acquired brain injury [1].

Every year, nine million people around the world suffer from stroke [2]. Globally, cerebrovascular disease (stroke) is the second leading cause of death and the eighth cause of severe disability in the elderly. The WHO estimated that in 2005, stroke accounted for 5.7 million deaths worldwide, equivalent to 9.9% of all deaths, and was the predominant cause of disability, afflicting 30.7 million people [2].

Statistical data show that after a stroke, one third of patients die during the first month, and 40% of people who recover from the acute phase exhibit a high degree of impairment that decreases their independence and quality of life. Only one third of patients recovers their basic functions and can resume a normal life [3]. There are not accurate data on the prevalence of TBI in Europe, meanwhile data from the United States show a high prevalence of this pathology, with 5.3 million people living with a disability caused by TBI [4]. New techniques of early intervention and the development of intensive ABI care have noticeably improved the survival rate. However, despite of these advances, brain injuries still have no surgical or pharmacological treatment to re-establish lost function. Cognitive rehabilitation, as part of neuropsychological rehabilitation, has been defined as the application of techniques and procedures, and the implementation of supports to allow individuals with cognitive impairment to function as safely, productively, and independently as possible within their environment. The provision of cognitive rehabilitation thus becomes an essential part of the services to manage the complex disablement that ABI provokes.

The use of Information and Communication Technologies (ICTs) to develop a tele-rehabilitation and tele-assistance allows:

- To improve the quality of clinical services, by facilitating the access to them, helping to break geographical barriers.
- To keep the objective in the assistance centered in the patient, facilitating the communication between different clinical levels.
- To extend the therapeutic processes beyond the hospital, like patient's home.
- A saving for unnecessary costs and a better costs/benefits ratio.

In the last years, several projects have been trying to demonstrate this utility of the ICTs as a better way to perform the neuro-rehabilitation.

The objectives of this paper are:

- Analyzing and modeling a tele-rehabilitation system, defining the objectives and user's requirements.
- Defining the platform architecture, highlighting the different modules involved.
- Designing and developing the platform, including the user interface, describing the different functionalities of the system for each defined profile.

PREVIRNEC [5] is a tele-rehabilitation platform that has been developed during the past six years by the Universitat Rovira i Virgili and Universidad Politécnica de Madrid, together with the Institut Guttmann (Spain) neuropsychology and research departments. The use and experience reached during this time with more than 500 patients been treated with PREVIRNEC, together with a deep study of the clinical problem and a modeling process of the system, have allowed the authors to improve considerably the system, creating a more complete cognitive tele-rehabilitation platform that is presented in this paper.

This paper starts with the system modeling, describing the different user profiles defined. Then, comes a description of the tele-rehabilitation itself, explaining their modules and the significant work done to achieve the objectives. Finally, some conclusions are shown.

II. SYSTEM MODELING

A. Requirements analysis

For the system modeling Unified Modeling Language (UML) has been used, describing the system's behavior using use cases and sequence diagrams.

For the elicitation and definition of the objectives and user requirements a detailed process has been followed, including interviews and meetings with neuropsychologists from the Institut Guttmann, which is a specialized center in cognitive and functional neuro-rehabilitation.

B. User Profiles

For each person or entity using the system in a determined context and for a specific goal, four different user profiles have been defined:

- **Patients:** man or woman of any age with one or some cognitive functions affected, as a consequence of suffering ABI. Here appears the *caregiver* role, considered a secondary actor that will help the patient to use the system when necessary.
- **Therapist:** a neuropsychologist specialized in cognitive rehabilitation in patients with ABI, who will have a number of assigned patients to be responsible for their treatment, scheduling and monitoring personalized and individualized therapies.
- **Supervisor:** person in charge of the user management for each center, both patients and therapists and their

assignments, apart from other management and control functions applied to center/s that supervises.

- **Administrator:** apart from all the typical administration tasks for every informatics system, the administrator will be the responsible for managing the categories, functions and tasks defined in the system, which is the content the therapist will use to schedule therapy sessions to their patients.

III. COGNITIVE TELE-REHABILITATION PLATFORM

PREVIRNEC is a cognitive tele-rehabilitation platform, developed over an architecture based on web technologies. PREVIRNEC is conceived as a tool to enhance cognitive rehabilitation, strengthening the relationship between the neuropsychologist and the patient, personalization of treatment, monitoring of results and the performance of tasks.

A. Architecture

The architecture presented here consists of five main modules, which group related functionalities vertically, sharing the user interface that is personalized depending on the user's role. This interface is also multi-language, with Catalan, Spanish and English already implemented, but being open to support any other language. The system also has a help module, which guides the user in order to complete each action. Security aspects are transversal and have to be taken into account in every module to keep information and all connections safe, due to the important of confidentiality in this kind of medical applications. The security module is the responsible of controlling every access, included the ones related to the patients' Electronic Health Record (EHR).

In Figure 1. this architecture is represented, where we can see the different modules, described below:

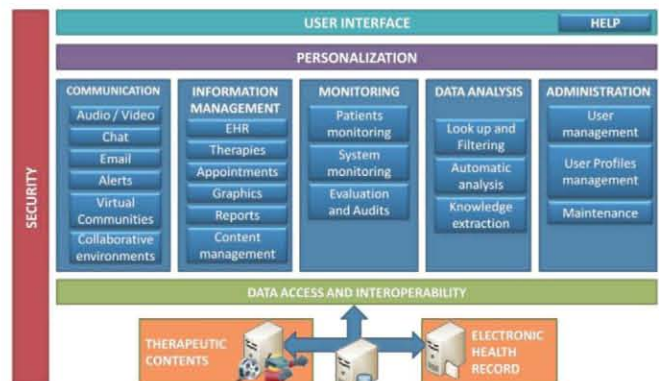


Figure 1. Tele-rehabilitation architecture modules

- **Communication:** the main element of this module is the videoconference that allows the users to communicate using video, audio and chat. Using the videoconference therapists can do tele-appointments with patients or other therapists, breaking the distance barriers between users, and helping the patients to feel

closer to the clinical team. Apart from the videoconference, this module has a mailing service to exchange internal asynchronous messages and an alert service that let users know what tasks they have to accomplish.

- **Information management:** this module groups functionalities related with the generation and edition of information that depends on the patient's EHR. Interoperability with the clinical information system has been achieved in order to use the patient's data stored in the centers. Besides, this module controls the assignation of therapies to the patients, determining which computerized tasks a patient has to do in a certain day. The results of the execution of these tasks are registered in the system, and then can be used by the clinicians to see the evolution of the therapy, as well as showing graphics and reports related to the completion of the sessions, tasks that have been used, both global and individual results, and many more.
- **Monitoring:** in order to comply with the Data Protection Law every action carried out by any user is stored in both the database and also in a log file, so the administrator can track every action related to any patient and its data. Apart from this, the system offers a module to monitor the execution of the tasks, so the therapist can then reproduce a task as it was done by the patient. This allows the therapist to see exactly what a patient did in the monitored task, which is very useful because sometimes it is not enough to merely see the numeric results.
- **Data Analysis:** the main objective of this module is to extract the maximum knowledge from the information stored in the system. To achieve this there is a tool for knowledge management that is applied for each data collected, being able to filter, analyze and extract the necessary knowledge to help the neuropsychologists in their decision making. This module, by analyzing a set of data defined together with the clinicians, is able to assign a patient to an affectation profile. An affectation profile groups patients with similar characteristics using clustering techniques, in order to give the neuropsychologist information about how patients of the same profile have done a concrete task in the past, helping them to know how good a task is for that kind of patient. Moreover, this knowledge can be used to learn about the neuro-rehabilitation processes or to improve the designed tasks, modifying the ones that appear not to be appropriate for certain patients.
- **Administration:** this module, although it is the one with less functionalities and users, includes very important functionalities, like the users' management and their profiles, as well as the system monitoring (using logs).

B. User Interface

One of the main efforts of improvement for this new version of PREVIRNEC is the redesign of the user interface. This new design, apart from including all the new functionalities, has been based on the User-centered design model, which principles are a new definition of those from classic ergonomics and, in general, from the accessibility guides. At this point, it is important to enhance how difficult is to have an interface accessible for everybody, even more when the target users are patients who suffer ABI and as a consequence of this they have problems in their cognitive functions.

In the design of the user interface phase we have used an iterative mock-up to show the experts not only how it would look like, but also the different functionalities the users will find and how they will perform every action.

C. Contents and centers organization

The tele-rehabilitation sessions consist of computerized tasks, grouped by functions and categories. The neuropsychologist creates a tele-rehabilitation session by assigning a set of tasks to a certain day, being able to configure the difficulty of each task, by setting some input parameters.

The new concept of category has been created to treat different collectives apart from the initial ABI patients, such as the elderly, schizophrenia, childhood, and more.

Every category will cover different cognitive functions and subfunctions. Therefore every task will be particularly designed by neuropsychologists for a cognitive subfunction (e.g., sustained attention or visual memory) that can be used for a specific collective (category).

PREVIRNEC can be used not only in the Institut Guttmann, but also in other clinical centers and even neuropsychologists who work by their own. Besides, each center defines three assistance areas by default (generic, home and test), but they can also create new areas as needed. This gives the possibility to study separately, for example, patients that have been treated at the clinical center from those who execute tasks at home

Moreover, the system administrator defines the categories for each center, selecting for every category the specific tests used for the neuropsychology exploration. These tests allow neuropsychologists to determine the affectation grade of each cognitive function.

D. Technologies

As we have already said, the platform is based on open source web technologies. The main architecture of the platform is based on a client-server communication using HTTP and XML-RPC, as it is shown in Figure 2.

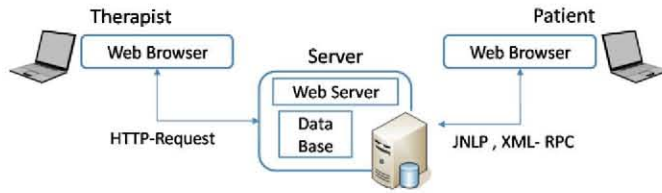


Figure 2. Client-server communication schema

In the developing phase, a Model-View-Controller pattern has been followed, so the view and the logic to access and process data are separated.

The new web application requires Java (jdk 1.6, jre 6.x) and it runs over Apache Tomcat 6.X, as it is based on Servlet/JSP. The database used is MySQL Server 5.X and MySQL Java Connector 5.X (JDBC). However, thanks to this division between data process and the view, the platform could be easily adapted to new other database models or new languages for the graphic user interface.

Relating to the programming languages used all the environment is Java 2 Platform (J2EE, Enterprise Edition), using JavaScript and AJAX (SACK library) to dynamically change the data showed on the HTML pages, so avoiding to reload the page every time the user wants to show or edit contents.

For the videoconference module OpenMeetings has been used, which implements the Real Time Multimedia Protocol (RTMP), using a red5 server for the audio and video streaming. One of the main challenges addresses in this work has been the implementation of a web-based videoconference application, so the user does not need any local application installed in their computers.

For the knowledge analysis, Weka has been used. Weka is a collection of machine learning algorithms for data mining tasks. This is the second main challenge of the work done, that is the process that groups patients into different clusters, helping the therapists to assign the more suitable task to each profile.

IV. CONCLUSIONS

The improvements on the platform presented in this paper have been tested with patients and neuropsychologists from the Institut Guttmann with very promising results. In the near future PREVIRNEC is expected to extend to the patient homes and other 17 centers.

The first results reveal that the platform is now more efficient and powerful thanks to the new functionalities added. The neuropsychologists particularly highlight the new design of the user interface that allows, for example, the possibility to see the results of a previous rehabilitation sessions while they are scheduling new ones. The

development of the interoperability module that shows the patient's EHR is also well considered. Regarding the new content and center classification, users emphasize how this platform is open to future neuro-rehabilitation applications, allowing new centers to configure the system and manage their own users. Finally, neuropsychologists also find very useful the knowledge extracted by the data mining module, which helps them when assigning tasks to a specific patient.

As a conclusion, PREVIRNEC is revealed to be a powerful tele-rehabilitation platform, letting the patients to extend their treatment beyond the clinical centers, reducing travel costs and the distortion of the rest of the family, while neuropsychologists can monitor and evaluate their evolution.

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